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PUBLIC HEALTH BULLETIN No. 32

# HOOKWORM DISEASE

(OR GROUND-ITCH ANEMIA)

## ITS NATURE, TREATMENT AND PREVENTION

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BY

CH. WARDELL STILES, PH. D.
*Professor of Zoology, Hygienic Laboratory*

PREPARED BY DIRECTION OF THE SURGEON-GENERAL

(THIRD EDITION)

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Figures 16–23.—Various views of the Old World Hookworm (*Agchylostoma duodenale*), showing how it wanders from the skin to the intestine. Prepared from a series of slides presented to the United States Public Health and Marine-Hospital Service by Prof. Arthur Looss, of Cairo, Egypt.

Figures 24–29.—Various views of privies, showing how soil pollution occurs, and how to prevent it.

# HOOKWORM DISEASE

## (OR GROUND ITCH ANEMIA):

## ITS NATURE, TREATMENT, AND PREVENTION.

By Ch. Wardell Stiles, Ph. D.,

*Professor of Zoology, Hygienic Laboratory, United States Public Health and Marine-Hospital Service.*

### INTRODUCTION.

The present paper is prepared to meet a constantly increasing demand for a general discussion on hookworm disease. It is intended primarily for physicians. For further details the reader is referred to the bibliography at the end of this paper.

### CAUSE OF HOOKWORM DISEASE.

Hookworm disease, known technically as Uncinariasis, is caused by small round worms belonging to the subfamily *Uncinariinæ*. There are a number of different species of hookworms known for various animals, as man, dogs, cattle, sheep, swine, seals, etc., but the forms which occur in man are peculiar to man and do not reach maturity in our domesticated animals; neither do the forms which occur in the latter develop to maturity in man.

For man, two different species of hookworms are known, namely, the New World form (*Necator americanus*) and the Old World form (*Agchylostoma duodenale*). The vast majority of cases of hookworm disease in man in the United States are due to the New World hookworm; but occasionally cases are found which are caused by the Old World parasite. The latter cases are usually, if not always, found either among immigrants or in native-born Americans who have been outside the United States.

The New World hookworm (figs. 1, 14, and 15) is a slender worm, about half an inch long and scarcely thicker than a small-sized hairpin.

In its adult stage the parasite lives in the small intestine, especially in the upper half, occasionally also in the stomach. It attaches itself to the intestinal wall, wounds the mucosa, sucks the blood, eats the epithelium, and, according to present evidence, it apparently produces a poisonous substance which injures the host.

## SYMPTOMS.

At least two distinct stages must be recognized for hookworm disease; but in case of repeated infections both stages may be present at the same time. These stages are the *cutaneous* (p. 7) and the *intestinal* stage (p. 7).

### CUTANEOUS STAGE.

The young hookworm larvæ (fig. 16) may gain entrance to the body either through the skin or by being swallowed. When they enter through the skin they cause a condition known in the South as "ground itch," "foot itch," "toe itch," "dew itch," "dew poison," etc.

"Ground itch" has not been thoroughly studied as yet. It is, however, established beyond question that numerous cases of ground itch are due to hookworm invasion. In addition there are many cases of so-called "ground itch" which do not appear to be followed by the intestinal stage of hookworm disease. The explanation of this is not as yet altogether clear; but several possibilities suggest themselves. The possibility is, for instance, present that some cases of ground itch are due to the parasite of Cochin-China diarrhea

FIG. 1.—Male and female hookworms (*Necator americanus*), natural size.

(*Strongyloides stercoralis*), which is very common in some tropical and subtropical countries. Again, it is by no means impossible that the hookworms of some of our domesticated animals may cause ground itch in man, although no case has been found in which these parasites reach maturity in the human being. Still a third possibility is that what we now term "ground itch" may eventually prove to cover a number of distinct conditions, the causes of which are at present not thoroughly understood.

In my experience about 87 per cent of hookworm cases definitely admit a history of ground itch.

Treatment of ground itch is not altogether satisfactory, if by satisfactory treatment is meant an abortion of the disease. The local irritation can be somewhat relieved, although the young hookworms will not thereby be killed. The infected portion should be kept thoroughly clean, as by washing with warm water and green soap, and then treated with some disinfecting substance, such as carbolized vaseline, zinc ointment, etc.; in addition it is well to bandage the infected area and to have the patient wear shoes and stockings, in order to prevent him from scratching the lesion.

INTESTINAL STAGE.

From the skin the young parasites wander to the intestine, as described on pages 37–38. Their effects upon the patient vary according to the physical condition of the latter, the intensity of infection, and perhaps also according to other factors not yet thoroughly understood. The "dirt eater"[a] represents the typical extreme case of hookworm disease, and the intensity of symptoms may vary from those observed in the "dirt eater" to cases in which the patient is not aware of any subjective symptoms, and in which the infection may not even be suspected until found by a chance microscopic examination.

The description of the symptoms given here is based, in general, upon the severe infections as found in the white race. The symptoms may, of course, be less intense in lighter cases.

In general, the patient, if infected before puberty, is retarded in his development, both physical and mental, and shows a more or less extreme anemia. A person 21 years of age may appear not better developed than one 14 to 18 years old.

External appearance.—*Skin:* In general, the skin is dry, and there is a noticeable absence of perspiration. The color may be waxy white to dirty yellow; it has a resemblance to tallow, especially on the forehead and on the alæ of the nose, and the observer seems to look through the superficial layer down into a deeper layer. Atrophic areas of the skin may be seen in cases of long standing.

*Hair:* The hair of the head is dry, reminding one of hemp. The beard, axillary, and pubic hairs may be very late and scant of growth.

*Edema:* Edema may be present on the face, feet, legs, scrotum, or entire body. It seems to be especially common over the cheek bones, and may frequently be noticed even in photographs.

*Wounds and ulcers.*—If a skin wound is present, it is likely to be rather slow in healing. Many of the patients (about 57 per cent of the well-marked cases) either show tibial ulcers or give a history of such lesions.

*Head:* The face is likely to show an anxious, ofttimes stupid expression. Dark lines under the eyes are common. The visible mucous membranes may be chalky white. The pupils show a tendency to dilatation, even when facing a strong light; many patients exhibit a peculiar blank stare; night blindness is reported in a number of instances. There is likely to be an edema over the cheek bones. The line of demarcation between the lips and skin may entirely disappear.

*Neck:* Cervical pulsation may be very prominent, and is frequently visible 6 to 12 feet distant.

---

[a] "Dirt eating" may, of course, develop from causes other than hookworm disease.

*Thorax:* The thorax may be so emaciated that the ribs stand out very prominently. The shoulders droop and are thrown forward; the shoulder blades stand out prominently (winged shoulder blades); frequently the observer can sink his entire hand below the median margin of the scapulæ, and even run his fingers for a distance between this margin and the ribs.

*Abdomen:* In many instances the abdomen is so swollen as to remind one of pregnancy. This condition is known locally as "pot-belly," "buttermilk-belly," or "shad-belly."

Digestive system.—The appetite varies exceedingly. There is a decided tendency to the development of an unusual desire for articles

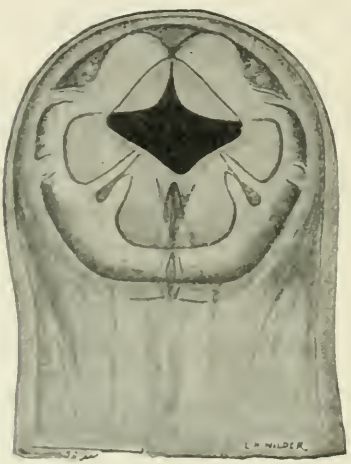


Fig. 2.

Fig. 3.

Fig. 2.—Greatly enlarged view of the head. The upper, rather quadrangular structure represents the mouth; just below are seen 4 cutting plates, or jaws, arranged in pairs and usually called lips, by means of which the worm attaches itself to the lining of the intestine; in the median line is seen a conical tooth-like projection, on the summit of which a gland opens. Original.

Fig. 3.—The same view, but at slightly deeper plane, showing the buccal cavity; one pair of plates and the "dorso-median tooth" stand out very prominently; at the side of this "tooth" is seen a pair of lancets. Original.

of food in some particular line, as for pickles, coffee, lemons, etc.; in very severe cases this tendency may take the direction of "dirt-eating," that is, the patient may eat wood, sand, clay, chimney soot, plaster, cotton, wool, etc.; one case, in which a boy ate three coats, thread by thread, in one year's time, has come under my personal observation. Usually patients will deny this habit, even when evidence of it is found in their mouth. I am now becoming persuaded that some of the tobacco chewing and snuff dipping, found in certain sections of the country, has its origin directly or indirectly in hookworm disease, for I have known of cases where parents taught

their children (one case, a boy 4 years old) to dip snuff and to chew tobacco in order to prevent them from "growing pale."

The stomach is enlarged in many cases. "Heartburn" and flatulence are common. Nausea and vomiting are reported. Pain and tenderness in the epigastrium are present. Ashford, King, and Gutierrez (1904) give this as "the most constant, most suggestive, and most clearly marked of all symptoms of the digestive tract." The tenderness is more marked on inspiration; it is median and continues toward the right, but is less marked and may even disappear toward the left. Frequently patients will shrink from the mere weight of the observer's hand at the points in question. Frequently there is tenderness on expiration in the eleventh dorsal intercostal space.

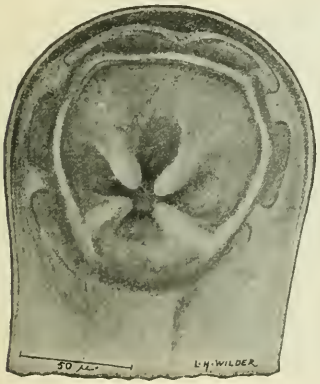



Fig. 4.

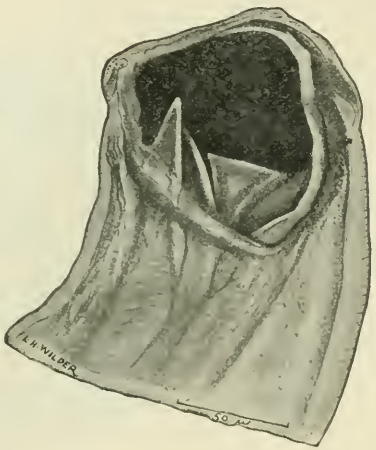



Fig. 5.

FIG. 4.—The same view, but at still deeper focus, and the specimen is in slightly different position. The four structures in the center represent the bases of the four lancets which guard the entrance to the esophagus, which is seen in the background. Original.

FIG. 5.—Lateral view of the head, at deep focus. In the buccal cavity are seen the prominent dorsomedian tooth and one of each pair of lancets guarding the entrance to the esophagus. By means of its powerful esophagus, the worm sucks down a portion of the intestinal wall into this buccal cavity against these pointed structures, as may occasionally be observed under the microscope. Original.

Constipation is so common that in some localities hookworm disease is known as "constipation;" diarrhea may, however, be present.

The feces vary in color. Authors are not in accord in regard to the presence of blood in the stools. The Porto Rican Commission found blood microscopically in only 6 cases and blood and mucus in 5 cases in over 22,000 fecal examinations. I have kept no statistics on this point, but I have frequently and repeatedly found blood, and there are autopsy records of large clots of blood in the intestinal canal.

Circulatory system.—The apex beat is pronounced in light cases; in moderate cases it may be displaced downward and to the left; in marked cases there is a reduction in the force of the apex beat, which is replaced by a wavy, indefinite pulsation in the epigastrium, or an impulsive, tumultuous heaving of the whole pericardium, and in these cases cyanosis, chiefly in the lips, may be noticed; a presystolic thrill is not infrequent in moderate and especially in severe cases (Ashford, King, and Gutierrez); in moderate cases, hypertrophy, especially of the left ventricle, causes an enlargement of the heart area; the murmurs are best heard in the third intercostal space; in moderate cases, hemic murmurs are almost always present (Ashford, King, and Gutierrez). Palpitation occurs early and is very prominent and constant. Dyspnea is very common, especially in the later stages.

Fig. 6.—Section through a worm, showing how it attaches itself to the intestinal wall. After a photograph by Dr. W. M. Gray, published by Gutierrez, Martínez & Sein, 1907.

The pulse varies from 80 to 132, without any necessary relation to the temperature; in later stages it becomes dicrotic, then weak and compressible, finally thready, irregular, and intermittent.

*Blood:* One of the most pronounced symptoms is the anemia, which is so common and prominent that it has been taken as basis for several vernacular names of the disease (miner's anemia, brickmaker's anemia, etc.); the common "cotton mill anemia" of our Southern States, popularly attributed to "breathing in the cotton lint," is nothing more nor less than hookworm disease.

For detailed descriptions of the blood condition, the reader is referred to the Porto Rican reports. In brief, in one series of 540 persons, compared as to race, Ashford, King, and Gutierrez (1904) found that the hemoglobin averaged 45 per cent in whites, over 44 per cent in mulattoes, and over 49 per cent in negroes. Of 577 per-

sons, the males averaged 41 per cent, the females 48 per cent in hemoglobin. In one case only 8 per cent is recorded. During the disease the hemoglobin falls before the red cell count, and may reach as low as 30 per cent before much change is noticed in the red blood corpuscles. In 26 cotton mill cases, Coward and I recently examined, the average was 62.6 per cent.

The red cells may fall as low as 754,000. In Porto Rico, 61 specially selected cases averaged 2,406,416. In 26 cotton mill cases in South Carolina, Coward and I found an average of 3,910,427. The red cells become polychromatophilic and show poikilocytosis.

The white cells usually vary from 5,000 to 10,000; leukopenia may be present in chronic cases. Little or no eosinophilia may be pre-

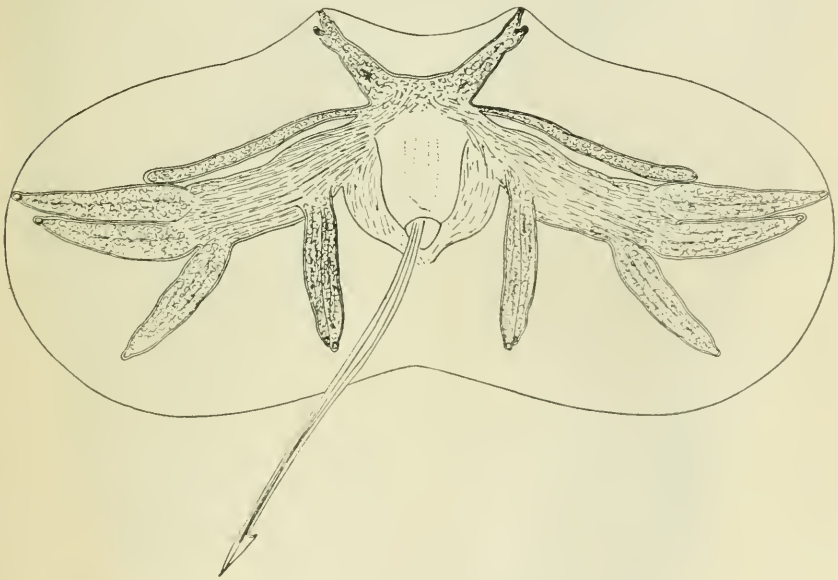


FIG. 7.—View of the umbrella-like expansion (bursa) on the tail of the male. Original.

sent in severe chronic cases with poor resisting power and exhausted blood-making organs; the Porto Rican Commission interprets a rise in eosinophiles as of good prognostic import; their "special" cases averaged 10.8 per cent before treatment and 13.2 per cent after treatment; this commission found the following averages in 29 cases, before treatment: Eosinophiles, 17.1 per cent; polymorphonuclears, 54.5 per cent; small lymphocytes, 16.3 per cent; large lymphocytes, 8.6 per cent; other leucocytes, 3.5 per cent.

RESPIRATORY SYSTEM.—Patients may complain of difficulty in breathing, especially after exertion.

TEMPERATURE.—The temperature may be normal, subnormal, or may reach 100° to 102° F.

Nervous system.—Mental lassitude, headache, and dizziness are frequently noticed, and patients are frequently noticeably timid. The effect upon the mind may be very marked. Children at school complain that it is difficult for them to study. Upon my examining school children for uncinariasis, the remark is frequently made to me by the teacher that I have picked out "the most stupid children in the school." The tendency of the children to ask to have a question

Fig. 8.—Lateral view of the tail of the male. Original.

repeated and then to repeat it themselves, before answering, is very marked.

The patellar reflex may be diminished or suppressed; tingling and formication may be present; either insomnia or somnolence may be marked; dizziness is common, especially upon suddenly rising to the feet; joint pains are common.

Muscular system.—The hand grip is weak and can not be long sustained. The muscles are weak and flabby, and movements are slow. The patient tires easily and on this account gains a reputation of being lazy.

Urinary system.—The urine may be neutral or alkaline, exceptionally acid; it is increased in amount, pale in color, and varies from 1,010 to 1,015 in specific gravity.

Genital system.—The effects of this disease upon the genital system may be very marked. If severe infection occurs in early childhood, puberty may be delayed for several years. I have known girls of 20 years, who menstruated only two or three times a year, then chiefly in winter, and girls of 18 to 26 who had never menstruated.

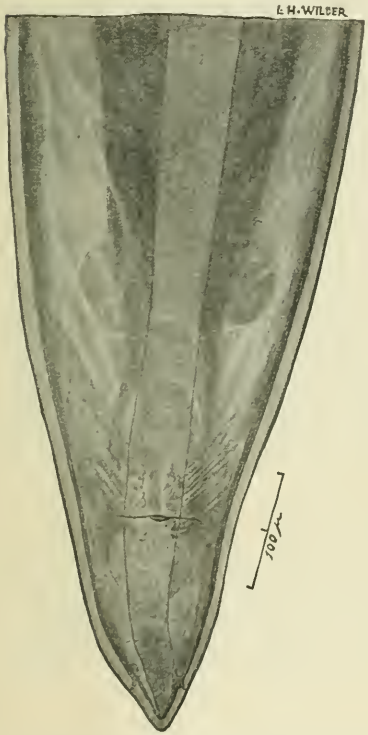



Fig. 9.—Ventral view of the tail of the female. Original.

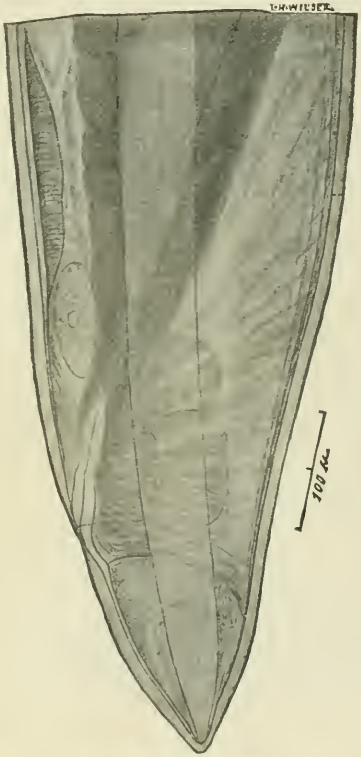



Fig. 10.—Lateral view of the tail of the female. Original.

The menstrual retardation and irregularity are in fact among the most prominent and most common symptoms noticed, and there is no room for doubt that hookworm disease is one of the most common causes of menstrual disorders among the southern girls, especially in the cotton mills and in the open country. It is in fact so common among such girls that it should be considered in connection with every case of menstrual disturbance found among them.

Abortions and miscarriages are common; sterility and impotence are reported as frequent.

### LETHALITY.

In connection with the lethality of hookworm disease it is important to note that this infection has both *direct* and *indirect* effects in the death rate. The Porto Rican Commission estimated that about 30 per cent of the deaths on the island were due to hookworm disease. We are not in a position to give exact data on this point for the United States. The view that this is a nonfatal disease is superlatively erroneous, but the more I study its effects the more I am persuaded that whatever may be the number of deaths *directly* due to hookworm infection, the *indirect* effects of the disease are equal to, perhaps greater than, the *direct* effects.

In tuberculosis, for instance, when good nourishment and fresh air are so important, the diseased condition of the intestinal canal and the lowered condition of the blood must have very serious results. Heiser's estimate that hookworm disease doubles the chances for death in cases of tuberculosis seems entirely reasonable.

Garrison's recent work in Bilibid prison (Manila) is very interesting in this connection. When the Americans took charge the death rate was 234; institution of sanitary reform brought this down to about 75; here it remained, until it was discovered that 52 per cent of the prisoners had hookworms; systematic treatment was instituted against intestinal parasites, and the death rate fell to 13.5. It is too early as yet to determine what proportion of this reduction is due directly to the freedom from hookworms and what proportion to other factors.

### EFFECTS IN LATER LIFE.

A person who is especially familiar with hookworm disease can frequently notice in adults quite clear evidence (in the color and quality of the skin, growth of beard, form and carriage of the shoulders, stature, hair, etc.) that a given person has had hookworm disease, probably in his youth.

### DURATION.

In case no reinfection occurs, a hookworm patient may retain part of his infection for at least six years and seven months, probably for about ten to twelve years. The present evidence, though incomplete, indicates that he will perhaps outgrow his infection in about ten to twelve years. One case has recently been brought to my attention in which, from present evidence, the infection seems to have existed for eleven years, although the patient was apparently removed from all chance of reinfection.

### DISTRIBUTION AND FREQUENCY.

GEOGRAPHIC.—Hookworm disease in man is a tropical and subtropical malady. In the United States, the Ohio and Potomac rivers

constitute, roughly speaking, the northern limit of endemic infection. Cases do, however, occur farther north, but such instances are rare in comparison with cases in the South, and probably most instances of infection recognized in the North are either imported from some other part of the country, or from some other country, or they are instances in which infection has occurred in mines.

RACIAL.—The indications at present are that the infection is more common, but with less severe effects, in the negroes than in the whites.

SEX.—Authors quite generally view hookworm disease as more common in males than in females, but my experience is the reverse. Recently, of 1,725 cases and suspects I have examined, 922 persons (or 53.4 per cent) were males and 803 persons (or 46.5 per cent) were females. This does not mean, however, that the malady is more common in males than in females, but simply that I examined more male cases than female cases, and if proportions are based upon the total number of persons seen the results are different. For instance, in one series of 440 cases, 242 were males and 198 females; but the 242 males represented 15.2 per cent of 1,583 males examined, while the 198 females represented 16.1 per cent of 1,225 females examined; thus while more male cases were actually found, the percentage of infection was greater among the females. The relative frequency in the two sexes will doubtless vary according to local conditions; for instance, in mining localities a higher percentage of infection may be expected among the males than among the females.

AGE.—Likewise authors assume that hookworm disease is more common in adults than in the young. This might easily be the case in a northern mining district, but is distinctly at variance with my experience in the United States, as is shown by the following tables:

| | |
|---|---|
| Over 20 years old | 272 suspects=18.5 per cent of 1,470 |
| Between 16 and 20 years old | 338 suspects=22.9 per cent of 1,470 |
| Under 16 years old | 860 suspects=58.5 per cent of 1,470 |
| Total | 1,470 |

The following table is even more exact as to the point at issue:

| | Males. | | | Females. | | | Total.[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Suspects. | Hands seen. | Per cent. | Suspects. | Hands seen. | Per cent. | Suspects. | Hands seen. | Per cent. |
| Over 20 years | 47 | 809 | 5.8 | 60 | 459 | 13.0 | 107 | 1,268 | 8.4 |
| 16 to 20 years | 51 | 246 | 20.7 | 58 | 319 | 18.1 | 109 | 565 | 19.2 |
| Under 16 years | 133 | 452 | 29.4 | 63 | 336 | 18.7 | 226 | 828 | 27.2 |
| Total[a] | 242 | 1,583 | 15.2 | 198 | 1,225 | 16.1 | [b] 1,026 | [b] 8,092 | 12.6 |

[a] In the foregoing table, the totals do not all agree with the sum of the respective columns, as some of the totals contain additional cases.

[b] 1,014 suspects in 8,069 hands of 59 mills, plus 12 cases in 23 mill hands examined microscopically in Augusta.

FIG. 11.—Hookworm eggs, enormously enlarged, in different stages of development. The series *a–g* is drawn from one and the same specimen, at different intervals from 10.45 a. m. to 12.05 p. m., and shows how rapidly the development takes place. Original.

Fig. 12.

Fig. 13.

FIG. 12.—Greatly enlarged view of a hookworm shortly after it has hatched from the egg. Original.

FIG. 13.—Figure of a worm about seven days old. This is the so-called "encysted stage" and is the stage which enters man. Original.

As to soil.—Other things (especially density of population and climate) being equal, hookworm disease is much more prevalent in areas with a porous soil (as a sandy soil) than in localities with a clay soil. For instance, in the clay belt which runs southward through the Carolinas, then westward through Georgia and Alabama, the infection is much less severe and less common than in the sandy areas toward the coast and in the mountain areas toward the west and north. It is easily conceivable, however, that special conditions as to density of population, shade, etc., might result in different results in a given area.

City and rural districts.—The average person who visits the South, visits a few cities such as Atlanta, New Orleans, etc. To him, unless he is an expert on hookworm disease, the statement that this is an exceedingly common disease might easily seem absurd. But no one really knows the South unless he knows the rural districts in addition to the cities.

In a city with a good sewer system hookworm disease will not spread (except for cases due to such factors as pollution of lots and alleys), hence cases need not be expected to be common.

In a village with a privy system the disease will spread in proportion to the number and style of privies and to the carelessness exercised in keeping the toilets.

It is especially in the rural districts, or among persons who have recently come from rural districts, that hookworm disease is found. This is due to the ignorance and carelessness exercised in the rural areas in respect to sanitary matters. In a tropical or subtropical region where over 50 per cent of the farmhouses and, according to estimate by competent educators, at least 30 per cent of the country schools, and even a much higher percentage of the country churches, have no toilet closet of any kind, hookworm disease has an excellent chance to spread, and in our rural South it is one of the most common of the diseases. My present estimate is that not less than 30 per cent of the rural inhabitants of our Southern States have hookworm infection. In some restricted localities fully 90 per cent have the infection.

Social condition.—While it is chiefly among persons in poorer financial condition, who live in insanitary surroundings, that we find this disease, hookworm patients are found also among the financially better classes and among the better educated, though the infections among the latter are usually less severe as well as less common.

In schools and colleges.—Colleges are known in which over 30 per cent of the students show infection on microscopic examination. Country schools are known in which 35 to 95 per cent of the pupils harbor hookworms.

In view of the effects which hookworms have on the nervous system, including inhibiting effects on mental processes, this disease must be viewed as important in connection with the subject of education, more especially in the rural districts.

In United States Army.—Several members of the Medical Corps of the Army have recently published very instructive statistics in regard to hookworm infection found among soldiers who were sufficiently able-bodied to pass the physical examination for enlistment into the army.

Dr. J. F. Siler reports 85 per cent of infection in 140 Southern recruits examined at Fort Slocum, N. Y.

Dr. W. P. Chamberlain examined 147 apparently healthy soldiers at Jackson Barracks, La. Of these, 43 were Southern-bred recruits received at Fort Slocum, and 29 men (or 67 per cent) showed infection. Among 57 Southern-bred soldiers who were in their first enlistment, infection was found among 31 men (or 54 per cent). Among 33 Southern-bred soldiers of more than three years' service infection was found in 4 men (or 11 per cent). Among 14 soldiers who had lived little or not at all in the South no infection was found.

Light infections in apparently healthy people, as found among soldiers and among college students, are of particular significance in connection with spreading the disease, as these persons act as "carriers" of the infection.

## DIAGNOSIS.

There are three methods of diagnosing hookworm disease—namely, by microscopic examination of the fecal material to find the eggs (p. 19); by judging the symptoms (p. 26); and by experimental treatment and finding the expelled worms in the stools (p. 26).

Microscopic examination of feces.—It is rare that the adult worms are seen in the discharges except during treatment, but the stools of hookworm cases contain the characteristic eggs (fig. 11) of the parasite, and by finding these eggs a positive diagnosis can easily be made. The Southern state boards of health and the Hygienic Laboratory of the United States Public Health and Marine-Hospital Service are making this examination free of charge.

*Ordinary technique:* For ordinary purposes the following technique is sufficient: Patients are instructed to furnish about half an ounce of their fresh fecal material. A small portion of this is taken up on the flat end of a toothpick (using a separate toothpick for each specimen) and smeared on a slide in a drop of water (personally I prefer the 2 by 3 inch rather than the 1 by 3 inch slide; and in hot weather or when the feces are especially offensive, trikresol is better than water); the smear should be uniform and not too thick; no stain-

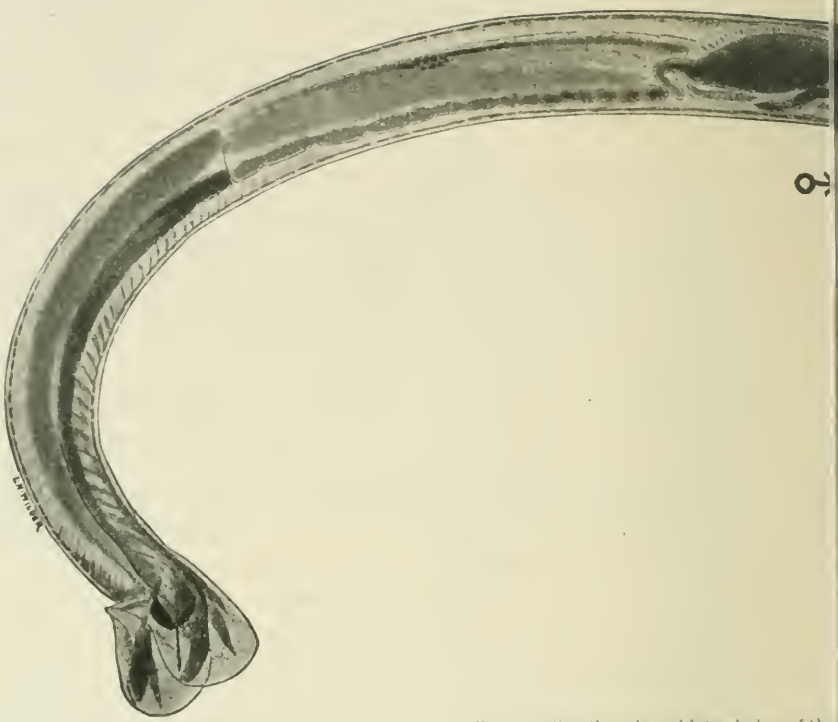


Fig. 14.—Greatly enlarged lateral view of the

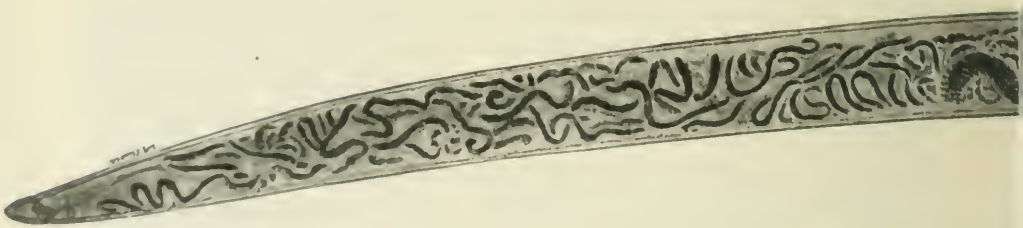
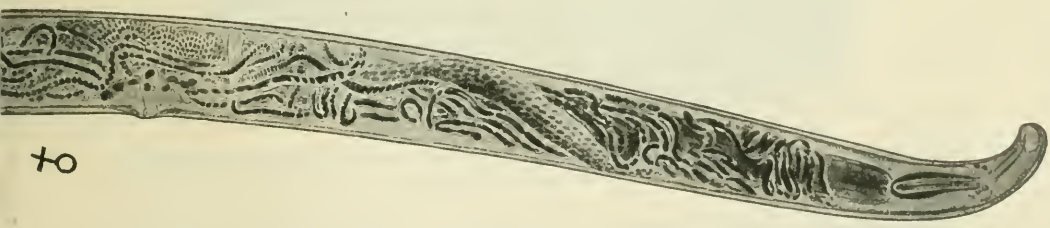


Fig. 15.—Greatly enlarged lateral view of the f

e (♀) hookworm (*Necator americanus*). Original.



e (♂) hookworm (*Necator americanus*). Original.

ing or drying is necessary; a cover glass (1 inch square is a good size) is placed over the smear, fluid is added under the cover if necessary or drained off in case too much is present, and the preparation is examined under an 8-millimeter (or one-third inch) objective. A mechanical stage is unnecessary. The manipulation of the slide is rendered easier if it is held lengthwise (if a 1 by 3 slide is used) rather than otherwise. In heavy infections the eggs will usually be found on the first slide, but at least ten such preparations should be examined before a negative opinion is expressed. It takes about thirty to sixty minutes to examine ten such slides properly.

FIG. 10.—Section through the skin of a dog within two hours after it has been infected with the Old World Hookworm.[a] Greatly enlarged.

Usually eggs will be found in fresh feces in the 4 to 8 cell stage (fig. 11). If in perfectly fresh specimens eggs are found in the 32-cell stage there is a chance that another parasite (*Trichostrongylus*) is present.

[a] Figs. 10–23 have been prepared from a series of slides of the "Old World Hookworm," presented to the United States Public Health and Marine Hospital Service by Prof. Arthur Looss, of Cairo, Egypt. They show how the worm wanders from the skin to the intestines. This discovery by Professor Looss represents one of the most important discoveries in modern medical zoology.

If free embryos are present in the fresh feces the probability is that the Cochin China worm (*Strongyloides stercoralis*) is present.

The mouth cavity of the hookworm embryo is about as long as the diameter of the embryo at the posterior end of mouth cavity; in the embryo of *Strongyloides* the mouth cavity is only about half as long as the diameter of the embryo at the posterior end of the mouth cavity.

If pressure is exerted on the slide, the outer covering of *Ascaris* eggs may rupture, and the beginner might possibly confuse these with hookworm eggs. The beginner in this work may also be confused by various vegetable cells found in the specimen, which he mistakes for eggs, or by plant hairs, which he mistakes for embryos.

FIG. 17.—The same cut transversely. Some larvæ are seen in the lymph capillaries.

Strawberry hairs, especially, are mistaken for hookworms by persons not familiar with this class of work.

*Bass's technique:* Experience shows that in some light infections the eggs are so few as to be easily overlooked. Bass has recently suggested a very novel method of concentrating these ova, by using salt solution, or, preferably, calcium chlorid, in a solution slightly heavier in specific gravity than are the eggs.

Bass (1909, June 15) describes his method as follows:

> The specific gravity of fresh uncinaria eggs is between 1,050 and 1,100. When they grow old this is increased in many specimens.
>
> A quantity of feces is well diluted with water, 1 in 10, and strained through gauze to get rid of coarse particles. This is centrifugalized, the fluid poured off, the cen-

trifuge tube refilled and centrifugalized again until all the diluted feces have been used. The precipitate is rewashed several times with water as long as anything can be washed out. To know just how long to continue the centrifugalization is the secret of success. One must learn just what is the proper time for his centrifuge. It should be carried out at high speed and just long enough to throw the eggs to the bottom. Too long centrifugalization defeats the purpose. With a centrifuge running 3,500 revolutions per minute, ten seconds at first, when there is much matter, and then four to five seconds is usually the proper time. The centrifuge must be steady. This gets rid of most very small things, those having flat, rough surfaces and those having a specific gravity about that of water. Now the precipitate should be washed as before, using calcium chlorid solution of a specific gravity up to 1,050. (Calcium chlorid is preferable to other salts because of its hygroscopic property. This was suggested by Prof. A. L. Metz.) This disposes of everything having a specific gravity below 1,050, and the precipitate may now be examined. There frequently remains a considerable amount of material, much of which is considerably heavier than the eggs and of such a character that it interferes much with their recognition. This

FIG. 18.—Section showing larvæ in axillary gland.

material may be removed by centrifugalizing with a solution sufficiently heavier than the eggs. A solution with a specific gravity of 1,250 is very satisfactory. In such a solution the eggs go to the top and other material below. With an appropriate pipette one may remove a few drops from the surface and examine, or, what is still better, pour off some of the top fluid containing eggs, dilute with water sufficiently to bring the specific gravity below 1,050 and centrifuge again. The precipitate will now contain most of the eggs contained in the original amount of feces and may all be put on one slide and examined. One such slide contains as many eggs as could be found in several hundred ordinary slide preparations of feces.

*Pepper's technique:* Dr. William Pepper (1908, March) has developed still another technique. The fecal material is much diluted with water and then centrifugalized in small quantities. The washing is frequently repeated, and when after each centrifugalization the supernatant dirty water is thrown away and fresh water added, the whole is then shaken up and again placed in the centrifuge. In this way the bacteria, free coloring matter, light vegetable matter, etc., are soon gotten rid of and only the heavier particles, including any

ova that may be present, will remain. After about six repetitions of this eliminative washing the sediment can be easily and satisfactorily examined under the low power of the microscope. There is then left no obscuring cloud of bacteria or fine granular débris, but instead each ovum stands out sharp and clear.

Pepper then goes on to say:

In endeavoring to remove some ova from a slide under the microscope prepared in this manner, by touching the egg with a very finely drawn out glass tube and thus causing it to be carried up into the tube by capillary attraction, it was found impossible with the ova of *Uncinaria*, the eggs having stuck to the glass. I have thus frequently transferred from one slide to another the ova of *Ascaris lumbricoides*, of *Tri-*

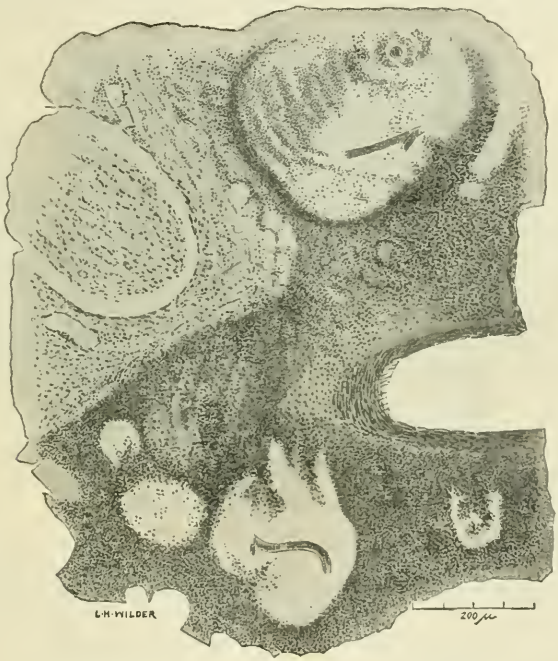



FIG. 19.—Section showing larvæ in lymphatics.

*churis trichiura*, and of *Tænia saginata*, and have never seen them adhere at all to the slide. A rather peculiar fact to be noticed in this connection is that the ova of the *Uncinaria*, although sticking closely to the glass slide, do not seem to adhere to any of the many other constituents of the stool. When a drop of this washed sedimented feces is allowed to stand on a slide for a few minutes and then gently immersed in water and examined microscopically, the eggs are found adhering to the slide while all else has been washed away. If additional drops are placed on the slide and washed off, the slide becomes thickly studded with the eggs. A ring of asphalt may be used to keep the drop when placed on the slide in bounds, and also serves to support a cover glass. Both the Old World and the New World variety act in the same way. The ova at all stages in their development behave in the same manner, even including those in which a living embryo could be seen moving within the egg. Ova were also seen to develop up to this stage while mounted in this way in water and under a cover glass, but were not observed to progress further. For demonstration purposes this method has proved very useful.

Diagnosis by symptoms.—The recognition of well-marked cases on basis of symptoms presents very little difficulty to one who is thoroughly familiar with this disease, but in general for every case so recognized, one to several cases will be in doubt or will entirely escape the clinician who may depend entirely on symptomatology.

Given a patient in the area of infection, with dry hair, dry skin, dilated pupil or with unusual tendency to dilatation, with tenderness in the epigastric region, continuing toward the right but with a tendency to disappear toward the left, with winged shoulder blades, shoulders sloping down and forward, slow of speech, tallow-like skin, poorly developed in general, anemia, scant pubic and axillary hair, a delayed type of menstruation, and a history of ground itch, espe-

Fig. 20.—Section through the heart, showing a larva in the center of the illustration.

cially if several such persons exist in the same family, and diagnosis is practically positive.

Diagnosis by experimental treatment.—As the state boards of health are making diagnoses free of charge, there is little if any reason for not having a microscopic examination made. At the same time the practical difficulty must be frequently faced that many rural people who have no objection to a microscopic examination of their sputum and urine do object very decidedly to furnishing samples of their stools. This may appear incomprehensible, but it is a factor which must be squarely faced. Again, in remote rural regions it is often impracticable to make several trips to the house to obtain a stool, and it is often impossible to induce the patient's family to take the trouble of sending a stool to the physician. In such cases almost the only plan to follow is to institute an experimental treatment and see if hookworms are passed.

TREATMENT.

The fundamental principle underlying the treatment of hookworm disease is the same as that which underlies the treatment of all other zooparasitic diseases, namely, first treat the parasite, not the patient. After the parasite is treated, attention may be directed to treating the patient.

Although hookworm disease may occur in persons in any walk of life, it is particularly among the poorer classes that it is found, and the average hookworm patient (children excepted, to a certain extent) can not afford to lose several days' wages to undergo treatment. It is therefore frequently expedient to conduct the treatment Saturday evening and Sunday morning. It will often be found difficult to arouse the interest of a community in regard to the presence of hookworm disease and the need of treatment. This can frequently be done, however, if it is borne in mind that the resulting anemia is, in common with other anemias, a frequent cause of amenorrhea.

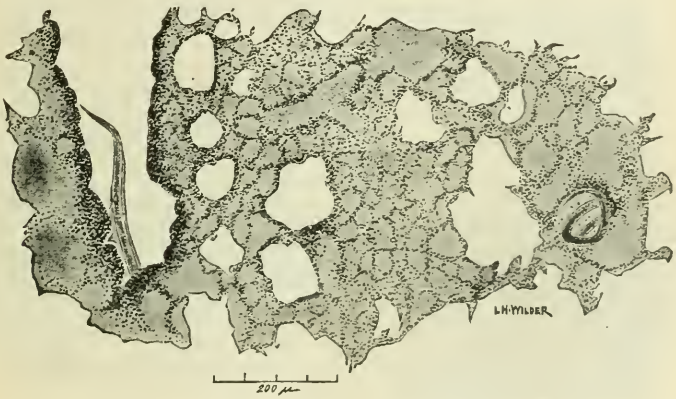



FIG. 21.—Section through the lungs, showing two larvæ.

WARNING.—Recalling that primarily we are to treat the parasite, not the patient, it should be remembered that if too great a quantity of thymol is absorbed by the patient, alarming symptoms and even death may occur. Accordingly, the patient and the patient's family should be carefully warned not to permit the patient under any circumstances to have on the Sunday during which the treatment is given any food or drink containing alcohol, fats, or oil. Patent medicines should be mentioned in particular, because of the alcohol many of them contain, and even milk and butter should be forbidden. I know of one case of serious thymol poisoning which followed promptly after the patient took a copious drink of milk the day thymol was taken.

PRELIMINARY TREATMENT.—On Saturday evening give a dose of Epsom salts. The reason is this: The hookworms are surrounded by more or less mucus and partially digested food. Unless this is

removed, the thymol may not reach the parasites, but may reach the patient, and this is contrary to what is desired, as the thymol is intended for the parasite, not the patient.

THYMOL TREATMENT ON SUNDAY.—(1) *Position of patient:* Instruct the patient to lie on his right side immediately before taking the drug and to remain in that position for at least half an hour after. The reason for this is that many of these patients have enlarged stomachs, and if they lie on their right side, the drug has the benefit of gravity in passing rapidly from the stomach to the intestine; but if any other position is assumed, the drug may remain in the dilated cardiac portion of the stomach for some hours and result in considerable complaint on the part of the patient and delay of the drug

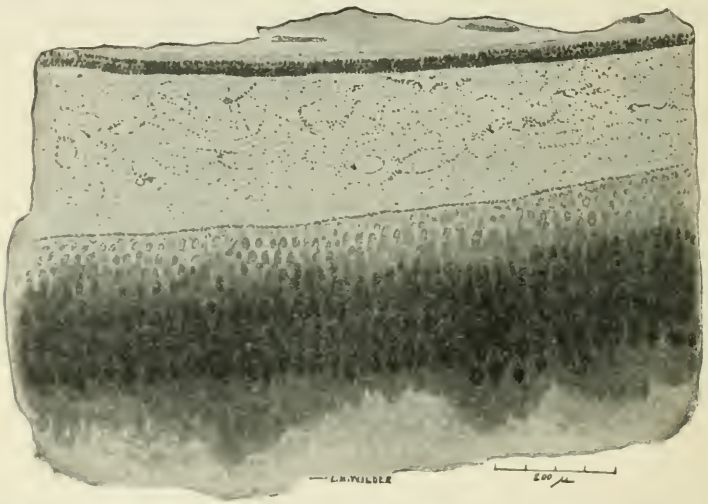


FIG. 22.—Section through the trachea, showing larvæ wandering free on the surface.

in reaching the worms. It is best for the patient to remain in bed until after 10 o'clock (see next paragraph).

(2) *Time of dosage:* The time of giving and size of dose may be arranged on either of two plans, depending on existing conditions.

(a) The plan usually followed is: At 6 a. m., one-half of the total dose of thymol; at 8 a. m., one-half of the total dose of thymol; at 10[a] a. m., Epsom salts (never castor oil).

(b) If the case is an especially severe one, or if the patient has, upon the first Sunday's treatment, complained of burning or other effects of thymol, the following plan is adopted: At 6 a. m., one-third of the total dose of thymol; at 7 a. m., one-third of the total dose of thymol; at 8 a. m., one-third of the total dose of thymol

[a] Some physicians prefer to allow a longer time (six to eight hours) to elapse between the last dose of thymol and the Epsom salts. If this plan is followed, it is wise to keep the patient under rather close observation.

(if unpleasant symptoms, as a sensation of severe burning in the stomach, have appeared this third dose should be omitted); at 10[a] a. m., Epsom salts (never castor oil).

(3) *Food:* No food is allowed until after the 10 o'clock dose of Epsom salts, but the patient is permitted to take a glass or so of water after the thymol, if he desires.

(4) *Thymol:* Finely powdered thymol in capsules, preferably in 5-grain capsules, should be used. A recently proposed modification in the dispensing of the drug promises excellent results; this is to powder finely the thymol with an equal amount of sugar of milk and to use the flat capsule (cachet) instead of the cylindrical capsule. By this method, the packing of the thymol, sometimes observed when the cylindrical capsule is used, is avoided.

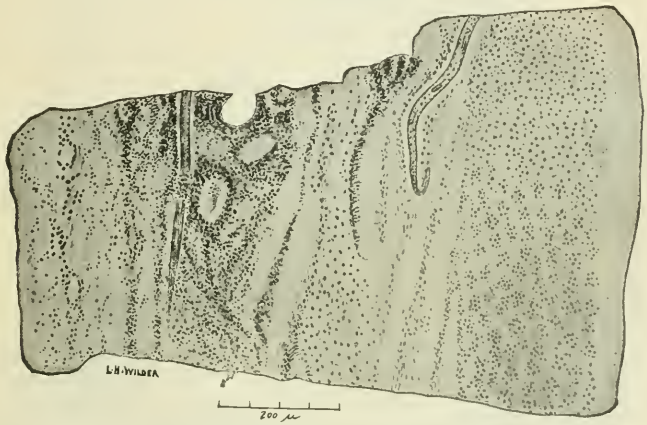



FIG. 23.—Section through the larynx, showing two larvæ.

(5) *General rule as to age:* In the table of dosage given in the next paragraph, the maximum dose per day to be adopted as a routine is given for various age groups. In determining the dose, however, the rule should be followed of taking the apparent rather than the real age and of not hesitating to cut down the dose even lower in case of unusually severe cardiac symptoms or other unfavorable conditions. Thus for a boy 16 years old, who appears to be only 12 years old, or in whom the anemia is especially marked, resulting in severe cardiac symptoms, the quantity of thymol should be reduced to the 12 or even the 8-year dose. Some authors give the impression that it is useless to give thymol for this disease unless the full dose is administered. This view is not in harmony with my experience.

[a] Some physicians prefer to allow a longer time (six to eight hours) to elapse between the last dose of thymol and the Epsom salts. If this plan is followed, it is wise to keep the patient under rather close observation.

(6) *Size of dose:* The following doses represent the maximum[a] amount to be used during one day's treatment for the age groups in question. This is practically the same table that the Porto Rican Commission has been using:

| | Grains. |
|---|---|
| Under 5 years old | 7½ |
| From 5 to 9 years old | 15 |
| From 10 to 14 years old | 30 |
| From 15 to 19 years old | 45 |
| From 20 to 59 years old | 60 |
| Above 60 years old | 30 to 45 |

Total dose, to be divided as indicated in paragraph (2).

FIG. 24.—An old privy, showing how soil pollution occurs.

REPETITION OF TREATMENT.—The foregoing treatment is repeated once a week, preliminary treatment Saturday evening and thymol on Sunday morning, until the patient is discharged.

DURATION OF TREATMENT.—To recognize whether the parasites are all expelled, and therefore to determine when to end the thymol treatment, either of two plans may be adopted, namely:

[a] Some physicians use larger doses, but the doses here given seem to be large enough

(a) *Microscopic examination:* On Saturday morning make 10 microscopic preparations of a fresh stool, or test the stool by the Bass method (see p. 23). If eggs are still present, repeat the treatment; if eggs are not found, discontinue the thymol. It takes about thirty to sixty minutes to make this examination of 10 slides thoroughly.

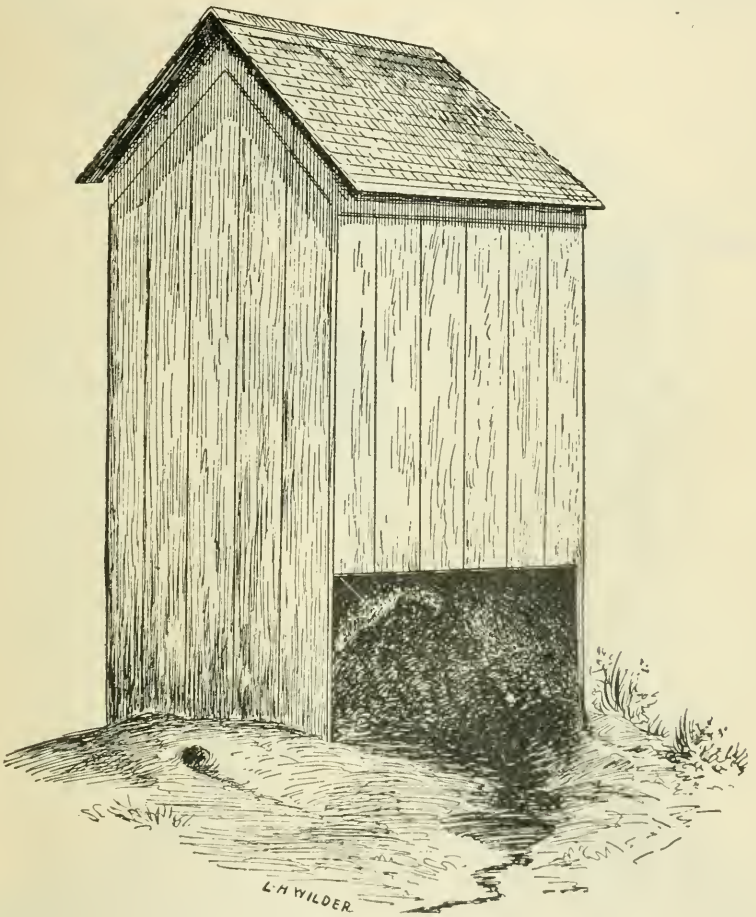



FIG. 25.—Rear view of a "surface privy, open in back," showing how soil pollution occurs. This is the most common style of privy in use in the South.

(b) *Cheese-cloth method:* A much easier way of recognizing the completion of the treatment, and for practical results nearly as satisfactory as the microscopic examination, is the following: Instruct the patient to wash all of his stools Sunday and Monday through a cheese cloth and to keep the cheese cloth moist and bring it to the office on Monday. While the fecal material will wash through, the worms will be retained in the cloth. Continue treatment as long as worms are found in the cheese cloth.

Other treatment.—If desired, iron may be administered on the days on which the thymol is not taken. It is a good plan, however, not to give iron during the first week, for it is quite important to convince the patient that the thymol treatment is the one which is really accomplishing the lasting good. If the drug is taken Sunday, the patient is likely to begin to feel some benefit by Wednesday or

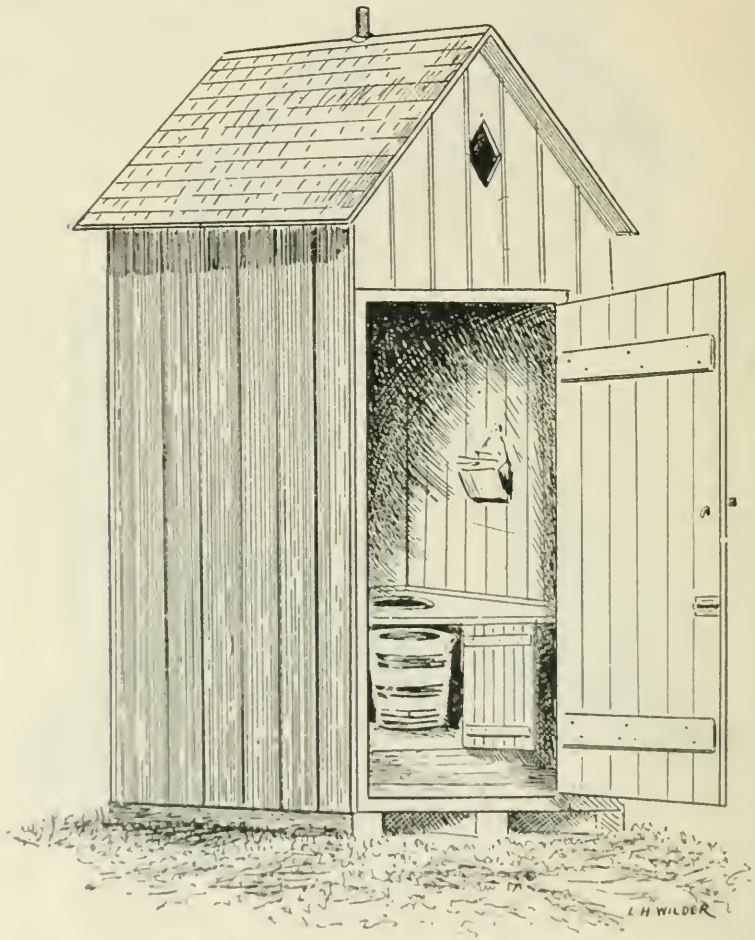



Fig. 26.—A floor privy, pail system, closed in back.

Thursday; his family is likely to notice it on Thursday or Friday. If iron is given during the first week the conclusion may possibly be drawn by the patient that it is really the iron which is causing the improvement, and he may discontinue the thymol. Of the two, the thymol is, of course, the far more important, for it reaches the parasite, while the iron reaches only the patient.

PREVENTION.

The life cycle of the hookworm, as described on page 37, makes it clear that hookworm disease is spread by soil pollution. As the eggs escape from the infected persons in the fecal material, it is clear that if this is properly disposed of, the infection will not spread.

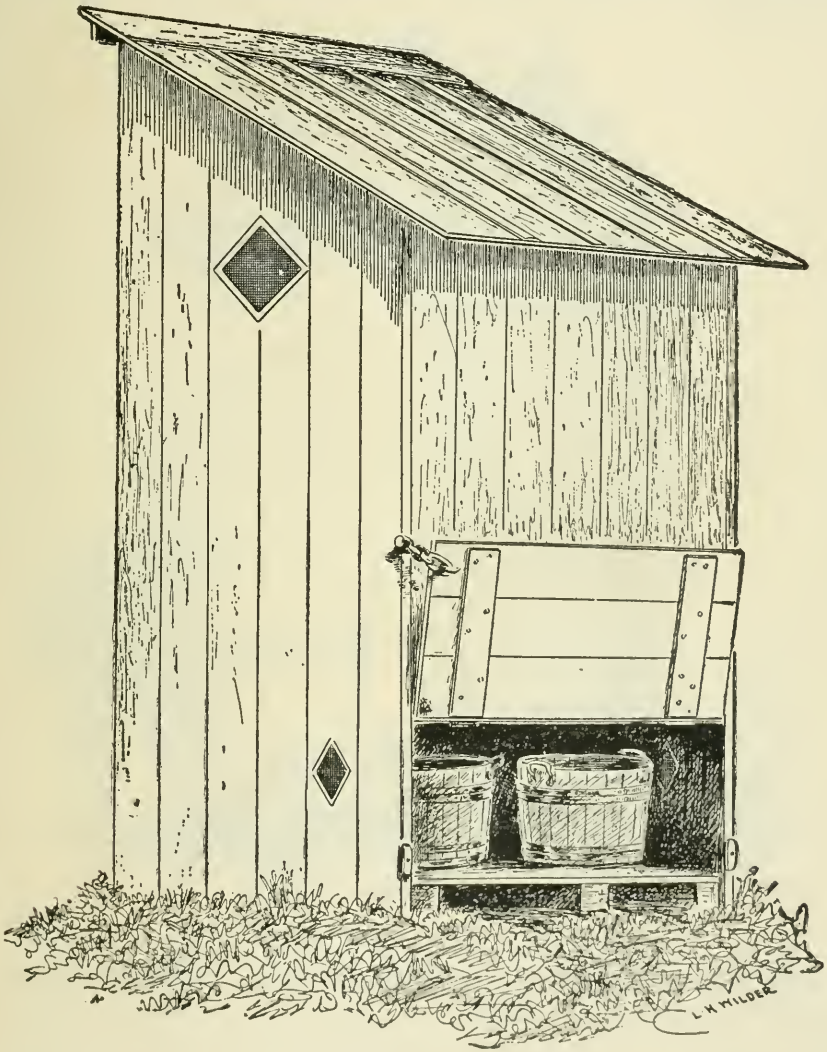



FIG. 27.—View of a floor privy, tub system.

Night soil should be burned, or boiled, or fermented, or it should be buried not less than 300 feet away and down hill from the water supply (well, spring, etc.). It should not be used as fertilizer unless it is first boiled or fermented, as in a septic tank. Soil pollution should be made a crime, punishable by fine or imprisonment.

The public should be warned to guard against ground itch, as this is so commonly the beginning of hookworm disease (or ground itch anemia). It is particularly in warm moist weather, or in moist places during warm weather, that ground itch is contracted. Accordingly, the infecting stage of hookworm disease is usually more common in the summer and early fall than during the winter and early spring.

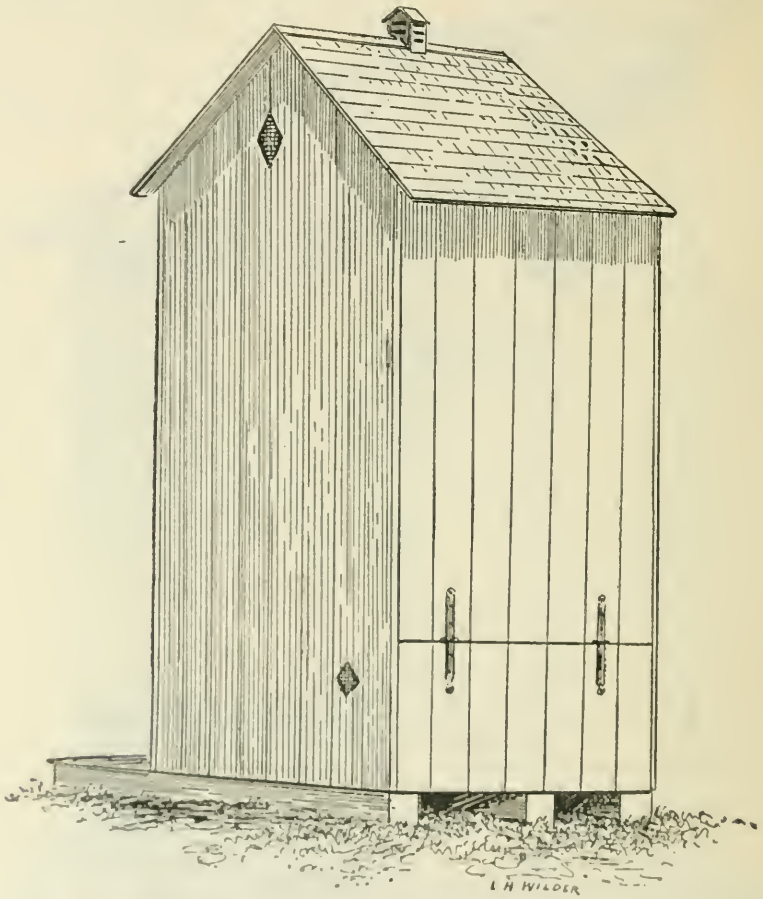



FIG. 28.—View of a floor privy, tub system, closed in back.

The existing infection in the South is easily understood if the sanitary conditions in villages and especially in the open country are studied. The usual style of privy found is shown in figure 25. With a closet of that type the spread of hookworm disease and of typhoid fever must be expected. Figure 24 shows the condition of the privy on too many farms. About 57 per cent of 3,369 farmhouses I have tabulated for six of the Southern States are even worse off than that, for they had no closet at all. Of 1,770 farmhouses occupied by whites 35.87 per cent had no privy, and of 1,599 farm-

houses occupied by negroes 80.42 per cent were without privy. Thus, a theoretical maximum of soil pollution was occurring around 57 per cent of the farmhouses examined, and as a soil polluter the negro is far in excess of the white. In a region where negroes, showing (p. 15) a relative immunity toward hookworm disease, bear a ratio to the white of 833 to 1,000 as inhabitants and 8,042 to 3,587

FIG. 29.—View of a floor privy, box system, closed in back. This system is somewhat cumbersome to work, and is not so likely to be water-tight as is the pail or tub system; further, also, repairs are more expensive and more difficult, if the closets are not made properly.

as soil polluters, their effect on the general health of the population must of necessity be marked.

To prevent hookworm disease it is necessary to prevent soil pollution. In rural districts this should be done by a compulsory privy law. In towns, it is best to license the privies at $3 to $5 per year and to use the money thus collected in removing the night soil and furnishing the tub and disinfectant.

Figures 27 and 28 show a toilet closet designed to prevent soil pollution. The following are the chief features of this outhouse: The floor extends under the seat and supports tubs or pails; the portion holding the tubs is closed in back by a door, hinged as shown in the figures; it is also ventilated at the sides, the ventilators being wire screened to keep out the flies; wire-screened ventilators are also located higher up on the sides and above the front door; the seats should be provided with hinged covers.

The tub should have a thin layer (say quarter of an inch) of sand or other dirt on the bottom and should be filled about one-fourth full with some fluid disinfectant, such as a 5 per cent solution of the compound solution of cresol (U. S. P.). In case of special necessity for economy, the tub may be filled about one-fourth full with water and a cupful of kerosene poured on it to keep insects away; in this event, however, care must be taken against throwing burning matches, etc., into the tub. The tub should be sufficiently deep and its floor sufficiently below the seat to avoid danger from splashing, but the top of the tub should come quite close to the seat.

If the South would adopt and enforce compulsory privy laws and use sanitary privies there would be a great reduction and gradual eradication of hookworm disease, and at the same time a great reduction in typhoid fever, amebic dysentery, and other soil-pollution diseases.

For a more detailed discussion of the sanitary privy see Public Health Bulletin 37.

According to the statistics given in the last census, the average typhoid death rate[a] for the entire country was 46.5 deaths per 100,000 inhabitants, and the average negro population 11.6 per cent.

Fifteen States, which stand above the average in negro population, average 34.34 per cent negroes and 72.70 typhoid deaths per 100,000 inhabitants.

Seventeen States, which have at least 1 per cent but not over 10 per cent negro population, average 2.48 per cent negroes, and 39.25 typhoid deaths per 100,000 inhabitants.

Eighteen States, which have less than 1 per cent negro population, average 0.42 per cent negroes and 25.51 typhoid deaths per 100,000 inhabitants.

Thus not only hookworm disease but typhoid fever also follows the mediæval sanitary conditions which have followed the negro. And (p. 34) 35.8 per cent of the rural whites I have tabulated are

[a] These statistics are, of course, not complete, but as they are gathered by the same method in all the states of the nonregistration area, it is fair to use them in a comparative statement for nonregistration districts; if any injustice exists in this comparison, it is an injustice to the registration States.

living under sanitary conditions not better than those of 80.4 per cent of the rural negroes.

In some sections of the United States the sanitary conditions surrounding many rural schools and rural churches are scarcely other than mediæval. Because of an absence of a privy, soil pollution at these places may spread disease to the pupils and the infection may be carried to uninfected homes. An immediate and radical reform in the sanitary surroundings of such schools and churches is urgently needed.

## LIFE HISTORY OF THE HOOKWORM.

The adult hookworms live in the small intestine, occasionally in the stomach. They mate in the bowels, and the females deposit numerous eggs (fig. 11). The eggs do not, however, undergo full development until they are discharged with the fecal material from the host. Thus, every individual hookworm found in the intestine represents infection with a separate germ.

FREE LIFE.—After a short time (eight hours to several days), the period varying according to conditions of heat and moisture, a tiny embryo (fig. 12) develops in each egg. This embryo breaks through the eggshell and feeds on the ground or in the night soil. In the course of two days or so the embryo sheds its skin but continues to feed. After about a week the worm sheds its skin again, but continues to live inside of its discarded skin, and it no longer takes any food. During this development, the rapidity of which may vary according to circumstances, the worm undergoes a growth in addition to certain changes in structure. The worm which lives in its second cast-off skin (fig. 13) represents the infecting stage which enters man and is sometimes called the "encysted stage." It may live in this condition for five months, perhaps longer.

MODE OF INFECTION.—Infection may occur in two different ways, namely, per mouth or per skin.

*Mouth infection:* Formerly, infection by mouth was supposed to be the only method by which the worms entered the human body. Then, when the method of skin infection became known, opinion went to an extreme and there was a tendency to ignore or minimize the mouth infection. Opinion is now moving back again in the other direction and indications are accumulating to support the view that infection by mouth is by no means rare or exceptional.

*Skin infection:* If the infecting stage (fig. 13) gets upon the skin, either of persons who go barefooted or who handle infected dirt, the worm bores its way into the pores, as into hair follicles, and escapes from its surrounding sheath-like skin. It then starts on its passage through the body (figs. 16–23). It may enter the blood, pass through

the heart (fig. 20), filter out in the lungs (fig. 21), crawl up the trachea (fig. 22), down the esophagus, through the stomach, and find its way to the small intestine. In laboratory experiments on animals, the worms may be found in the intestine eight to fourteen days (possibly earlier) after the skin infection has been practiced. Arriving in the intestine, the worm sheds its skin two more times, becomes adult and mates, and Looss has proved in the case of the Old World hookworm that eggs may be found in the stools seventy-one days after infection.

Claude Smith found eggs in the feces six and one-half weeks and seven weeks after experimental skin infection on two persons with the American parasite.

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